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Maximum Power Point Tracking in Photovoltaic Solar Energy Systems using Hybrid PSO - GSA Method

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***Abstract*- Tracking of the maximum power point of a photovoltaic array is usually an essential part of PV systems. In general, PV generation systems have two major problems; the conversion efficiency of electric power generation is low, and the amount of electric power generated by solar arrays changes continuously with weather conditions. Moreover, the solar cell V-I characteristic is nonlinear and varies with irradiation and temperature. There is a unique point on the V-I or P-V curve of the solar array called MPP, at which the entire PV system operates with maximum efficiency and produces its maximum output power. The location of the MPP is not known, but can be located, either through calculation models, or by search algorithms. Therefore, MPPT techniques are needed to maintain the PV array's operating point at its MPP. In this paper, we have proposed a hybrid technique using PSO and GSA algorithms, which tracks maximum power point in a more linear and effective way than existed methods. This method uses combined ability of social thinking (gbest) in PSO with the local search capability of GSA to get the duty cycles for MPPT control. The experimental results show improvement in various terms with that of conventional method for MPPT tracking.**

Keywords- MPPT, Photovoltaic cells, Renewable energy

I. INTRODUCTION

In the current century, the world is increasingly experiencing a great need for additional energy resources so as to reduce dependency on conventional sources, and photovoltaic (PV) energy could be an answer to that need. PV cells are being used in space and terrestrial applications where they are economically competitive with alternative sources. Generally, PV systems can be divided into three categories: stand-alone, grid-connection and hybrid systems. For places that are far from a conventional power generation system, stand-alone PV power supply systems have been considered a good alternative. These systems can be seen as a well-established and reliable economic source of electricity in rural remote areas, especially where the grid power supply is not fully extended.

II. NEED OF MAXIMUM POWER TRACKER IN PV SYSTEMS

Currently, although the cost of the solar energy is still higher than that of energy from fossil fuels, the trend of oil shortage is one factor that increases the cost of fossil fuels and can eventually enable the cost of solar energy to be lower than that of energy from fossil fuels. In addition, the advances in the maximum-power-point-tracking (MPPT) algorithm used in solar photovoltaic systems and the resulting efficiency improvement of the inverter enable the cost of solar energy systems to be further reduced. Therefore, in the future, the cost between solar energy and fossil fuel energy may become closer to each other. However, due to the characteristics of the solar cell, the maximum power of the solar cell cannot be provided without the use of a MPPT controller. By using a MPPT converter, the input impedance of the converter can match the output impedance of the solar cell to achieve the maximum power output of the solar cell. Because of its clean and stable output power, solar photovoltaic systems using a MPPT converter will find a place in the field of the green energy application. The programmable advantage of the digital chip accelerates the research of the MPPT algorithm. Different algorithms have different tracking performances. Thus, determining how to obtain improved tracking performance using a simple algorithm is an important topic. By reducing the specification requirement of the digital chip used in MPPT, the use of a simple algorithm can reduce the cost of a PV system. Therefore, a MPPT method using a simple algorithm that provides good tracking performance is desired [1].

III. HIGHLY PREFERRED METHODS FOR MPPT IN PV SYSTEM

The characteristic curve of the solar cell exhibits a maximum power point. By feeding back the voltage and current values of the solar module to determine the maximum power point position and to provide the adequate duty cycle to the converter, the maximum power point can be obtained. The typical tracking method the "perturb and observe" (P&O) method [2].The P&O method is widely used because of its easy implementation. However, the P&O algorithm continues to operate, even at the maximum power point; as a result, the output power may be unstable, thereby decreasing the efficiency of power generation. Furthermore, P&O method also has the possibility of errors in determining the maximum power point. This error causes the tracking speed of the P&O method to decrease. The hill-climbing [3] and incremental conductance (INC)

[4] methods use the characteristics of the power and voltage of the solar cell to determine the maximum power point. The maximum power point occurs when the slope of the power–voltage curve of the solar cell becomes zero. However, perturbations in the zero slope state can still occur. Although some other tracking algorithms, such as fuzzylogic [5], neural-network [6] and swarm chasing [7], exhibit precise tracking capability, these algorithms are very complicated. In addition to the above methods, the fractional open circuit voltage and short current methods have also been proposed. The position at the eighty percent of the open circuit voltage is taken as the maximum power point. However, these methods must detect the open circuit voltage and short current periodically, and the aforementioned maximum-power point position is not the exact maximum power point. The above methods are classified according to the judgment algorithm. In addition, research studies on the variable step-size methods have also been proposed [8].In the conventional method, a fixed step size is applied to track the maximum power point. The use of a fixed step size will cause some problems because the step size cannot be changed in the neighborhood of the MPP. Although the MPP can be achieved, the system cannot produce stable output power if too large a step size is used, resulting in a reduction in the power produced by the overall system. To achieve a stable output power in the neighborhood of the MPP, the step size can be designed to be small, but at the cost of a slow dynamic response. To solve the above dilemma, the variable step-size method was proposed. With the variable step-size concept, fast dynamic response and stable output power can be obtained simultaneously. The variable step-size method has evolved from the Hill-climbing method. The step size of the Hill-climbing algorithm can be varied to achieve good tracking performance. Although the conventional variable step method exhibits good tracking performance, it also has the following problems. To solve the convergence problem, a constant value is often needed to be multiplied in the tracking algorithm. To keep the fast dynamic response and maintain a stable output power, the choice of this constant value is very important. A poor choice of the constant value causes the system to oscillate, thereby reducing the power generation. Another problem regarding the use of this constant value involves significant changes in the irradiation, which cause the power–voltage curve of the solar cell to vary significantly; because this constant value cannot be adjusted with the variation in weather, the dynamic response of the solar system will be slow when the irradiation exhibits a large variation.

IV. PROPOSED ALGORITHM

A. PSO (particle swarm optimization)

The particle swarm optimization (PSO) is basically developed through the simulation of social behavior of bird flocking and fish schooling. The PSO algorithm maintains a swarm of individuals (called particles), where each particle represents a candidate solution. Particles follow a simple behavior: emulate the success of neighboring particles and its own achieved successes. The position of a particle is therefore influenced by the best particle in a neighborhood, besti P and the best solution found by the particle itself, best G [9]. Particle position (i.e. Duty cycle), d_i^{n+1} is adjusted using $d_i^{n+1} = d_i^n + \Phi_i^{n+1}$ where Φ_i^{n+1} is the velocity and is calculated using

$$\Phi_i^{n+1} = w\Phi_i^n + c_1 r_1 \{P_{besti} - d_i^n\} + c_2 r_2 \{G_{besti} - d_i^n\} \quad \ldots\ldots \quad (1)$$

where w is the inertia weight, c1, c2 are the acceleration coefficients, r1, r2, are random numbers, P_{besti} is the personal best position of particle i, and best G is the best position of the particles.

B. GSA (Gravitational Search Algorithm)

The gravitational search algorithm is based on the law of gravity and the notion of mass interactions. The GSA algorithm uses the Newtonian physics theory and its searcher agents are the collection of masses [10]. The force is given by

$$F = \frac{GM_1 M_2}{R^2} \quad \ldots\ldots\ldots \quad (2)$$

where M1, M2 are the masses of particles 1 and 2 respectively, R is the distance between them, G is a gravitational constant, and F is the magnitude of the gravitational force. Newton's second law says that when a force F is applied to a mass, its acceleration a only depends on the force and its mass as given in equation below

$$a = \frac{F}{M} \quad \ldots\ldots\ldots \quad (3)$$

From this, the velocity and the position could be calculated as

$$\Phi_i^{n+1} = randi\Phi_i^n + a_i^{n+1}$$
$$d_i^{n+1} = d_i^n + \Phi_i^{n+1} \quad \ldots\ldots \quad (4)$$

Where *randi*, random variable in the interval [0, 1].

C. Hybrid PSOGSA

The basic idea of PSOGSA is to combine the ability of social thinking in PSO with the local search capability of GSA [11]. In order to combine these algorithms, (4) is proposed as follow:

$$\Phi_i^{n+1} = w\Phi_i^n + c_1 r_1 a_i^n + c_2 r_2 \{G_{best} - d_i^k\} \quad \ldots.(5)$$

where w is the inertia weight, c1,c2 are the acceleration coefficients, are random numbers, w is the inertia weight, r1,r2 and best G is the best position of the particles and a_i^n is the acceleration of agent i at iteration n is given by

$$a_i^n(t) = \frac{F_i(t)}{M_i(t)} \quad \ldots\ldots(6)$$

Therefore, the positions of particles are updated asfollow:

$$d_i^{n+1} = d_i^n + \Phi_i^{n+1} \quad \ldots.(7)$$

To start the optimization process, the PSOGSA algorithm transmits three duty cycles i d (i=1, 2, 3) to the boost converter. These values serve as the best values for the first iteration. For the next iteration, the new duty cycle is calculated from the previous duty cycles by decreasing or increasing linearly its value with regard to the change in array power by the ratioQ1. The change in array power and duty cycle can be obtained using

$$d_{new} = d_{previous} * Q1 \qquad \text{....(8)}$$

where $d_{previous}$ old d is the previous best V duty cycle and Q1 is given by

$$Q1 = \frac{P(d_i^n)}{P(d_i^{n+1})} \qquad \text{.....(9)}$$

To perturb the new duty cycle which is obtainedthrough (8), d1,d3 are equally displaced in positiveand negative directions, respectively by a factor of delta i.e.,

$$d_{i,new}^n = [d1 - delta, d2, d3 + delta] \qquad \text{.....(10)}$$

The value of 0.02 is selected so that the fluctuations in the operating power of the PV array will not be too large. This is to allow the PSOGSA algorithm to explore a wider range to track the global peak value. The objective function is defined as

$$P(d_i^n) > P(d_i^{n-1}) \qquad \text{....(11)}$$

From (11), it can be found that the new duty cycles will be varied according to the change in operating power but its value will always be very close to the new best duty cycle. Hence, the re-initialization of duty cycles will not be requires which would result in unnecessary exploring. This allows for the new MPP to be tracked very rapidly.

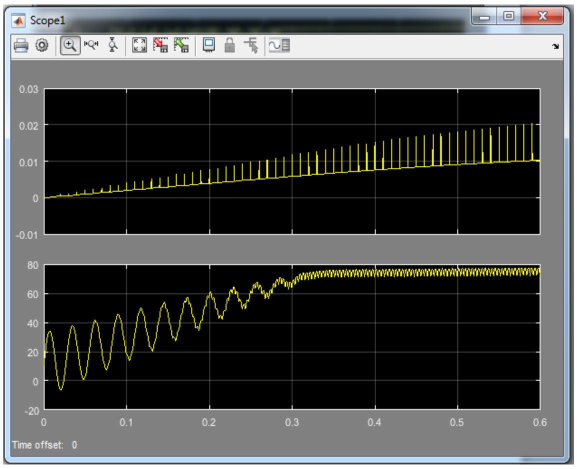

Figure 3: (a) current (b) voltage by hybrid method

By using the same parameters in all blocks such as temperature, irradiance value etc. proposed method performs well as compared to Perturb and observe method. P & O method gets poor tracking in the start and stables the Maximum power point after long period of time than the hybrid method. The second improvement that has been achieved by proposed method is that the range of power produced fluctuates less than the P & O method. The third improvement is that the hybrid method adapts linear increase in all three parameters in the start which matches with the real time behaviour of the solar cell instead of large fluctuations caused by P & O method.

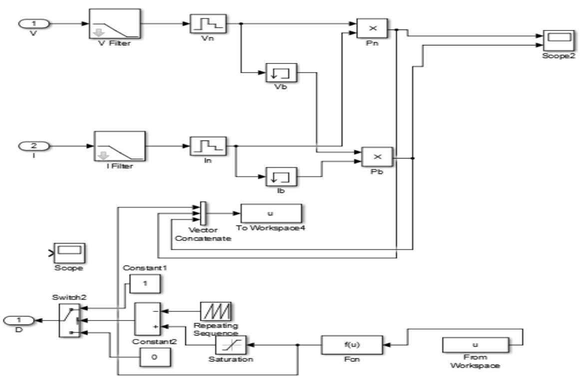

Figure 1: MPPT simulation block for hybrid method

The output of the algorithm has been shown in power, voltage and output current curves in the figures below

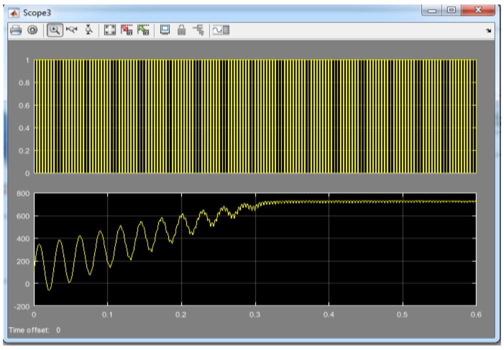

Figure 2: (a) Duty cycle (b) output power by hybrid metho

V. COMPARASION

Comparasion of traditional method & proposed method has been shown on the logarithmic scale.

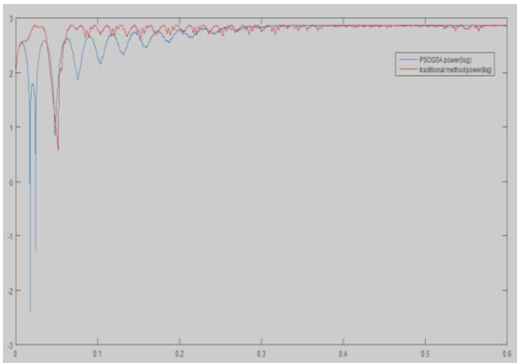

Figure 4: Comparison of P & O method and proposed PSOGSA hybrid method

CONCLUSION

Among the renewable energy sources, solar energy is a suitable candidate as it allows direct conversion of this form of energy to the electrical energy by using photovoltaic (PV) systems. Solar energy can be converted to the electrical energy by using a PV cell, albeit two limitations: a) Extremely low conversion efficiency, especially under low irradiation and b) the dependency of power generation on the current atmospheric conditions (e.g., solar radiation and temperature), aging, and load conditions. Therefore, it is ideal to maintain the PV operation at its maximum achievable efficiency at any time period. Therefore, the optimum design of PV system is crucial for extracting maximum power from a PV cell. However, the nonlinear behaviour of PV systems and the variations in the maximum power point (MPP) due to solar irradiance level and temperature complicate the tracking of MPP. It should be noted that the MPP can be achieved only at a specific operating point in the PV cells . In this work, we have proposed a hybrid method for MPPT purposes. This method uses combine ability of social thinking (gbest) in PSO with the local search capability of GSA to get the duty cycles for MPPT control. The experimental results shows improvement in various terms with that of conventional method for MPPT tracking i.e power output has been increased with less variations in voltage as compared to P & O method.

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